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Atomic force microscopy of titanium oxide nanosize structures resistive switching

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Modern microelectronics development is associated with the development of new energy efficient, high-speed memory elements that can be built on the memristor structures basis that switching between high and low resistance states [1, 2]. However, for the introduction of such memory elements into production it is necessary to conduct comprehensive studies of the time stability of their resistive switching.

Experimental studies were carried out on a titanium film with a about 20 nm thickness, obtained by the magnetron sputtering method on a dielectric substrate SiO_2. For this purpose, using a scanning probe microscope, nanolithography was carried out using local anodic oxidation (LAO), which resulted in the oxide nanosize structures formation with lateral dimensions of 3×3 μm^2 and a thickness of 5 nm on the thin titanium film surface. Studies of current-voltage characteristics showed that the structure obtained exhibits a memristor effect and switches between high and low resistance states (Fig. 1).

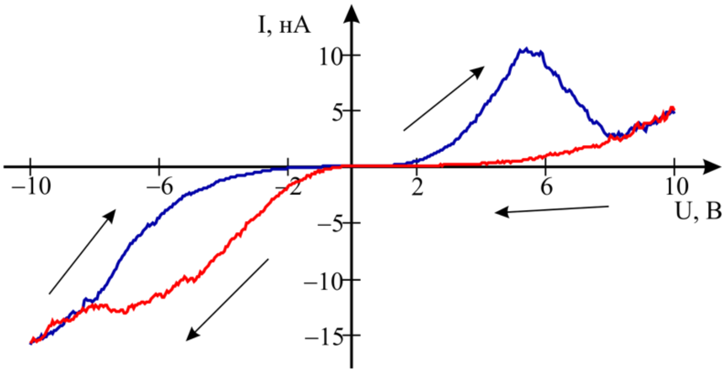


Figure 1. Volt-ampere characteristic of titanium oxide nanosize structure formed by LAO method.

Measurement and analysis of current-time characteristics (Fig. 2) showed that in the initial state, when positive voltage pulses are applied, there is no current through the memristor structure, which corresponds to the HRS state. When negative voltage pulses are applied, the current through the structure is of the order of 0.3 nA, which corresponds to the LRS state. The results obtained correspond to the memristor effect based on the modulation of the width of the potential barrier at the electrode/oxide interface.

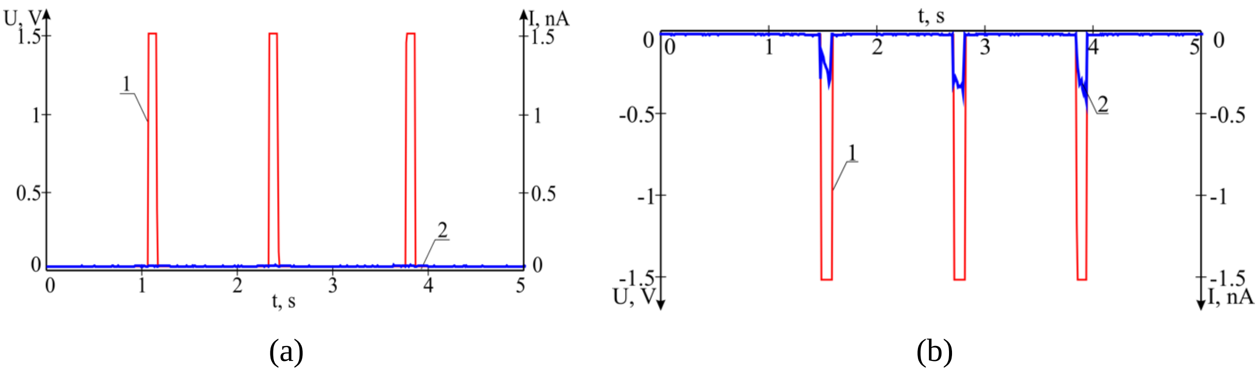
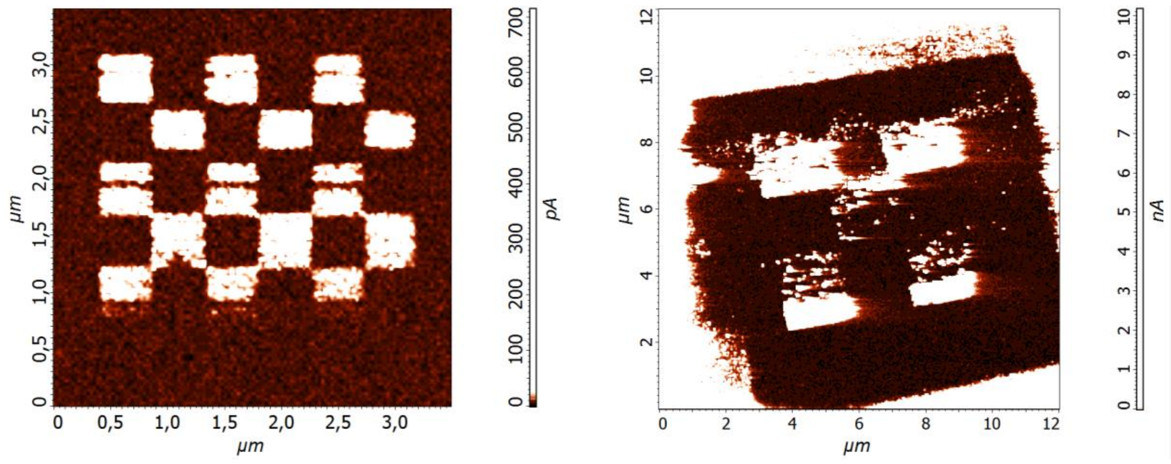


Figure 2. The current-time characteristics of the memristor structure based on the titanium ONS, obtained by applying voltage pulses (1) and current (2) of different polarity: (a) positive; (b) negative.



(a) (b)

Figure 3. AFM images of the current distribution of test areas in the LRS state on the surface of the memristor structure: (a) after formation; (b) after 75 days.

To study the time of information storage in memristor structures on the ONS surface using AFM the test area was formed and its resistive switching to the LRS state by applying negative voltage pulses with an amplitude of -6 V. Scanning in the spreading resistance mode with the application of 1.5 V voltage pulses allowed us to construct a map of the current distribution of this test area on the surface in the LRS state (Fig. 3a). Then, after 75 days, the structure was scanned in the spreading mode, which showed that the test areas were saved in the LRS state (Fig. 3b).

Thus, it was shown that oxide nanoscale structures of titanium, formed by the method of local anodic oxidation, exhibit a stable memristor effect for a long time. The obtained results can be used in the development of technological processes for manufacturing the elemental base RRAM based on oxide nanosized titanium structures using probe nanotechnology.

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2. R.V. Tominov, V.A. Smirnov, V.I. Avilov, A.A. Fedotov, V.S. Klimin, N.E. Chernenko, *IOP Conf. Series: Mat. Sci. Eng.* **443**, 012036 (2018).